Aug 29, 2016

Active stereo vision system for object position estimation

Lab Seminar

Han Sol Kang

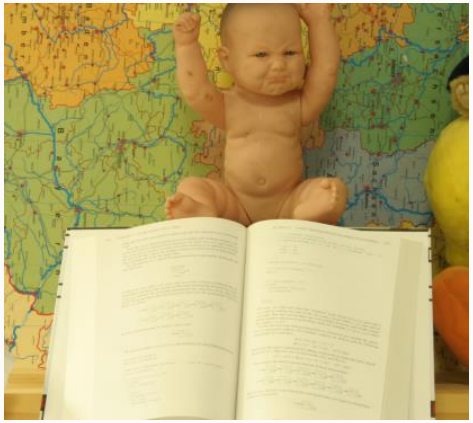
Contents

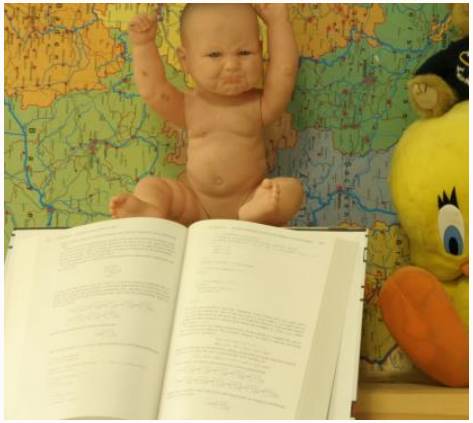
Introduction

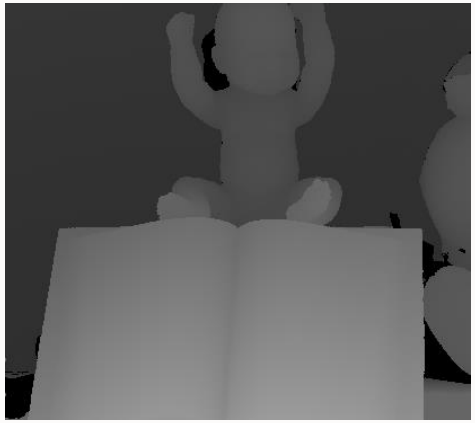
Conventional Stereo Vision

❖ Conventional Stereo Vision

: Stereo vision is the extraction of 3D information from digital images, such as obtained by a CCD camera. **By comparing information about a scene from two vantage points**, 3D information can be extracted by examination of the relative positions of objects in the two panels. This is similar to the biological process **stereopsis**.







Introduction

Active Stereo Vision

❖ Active Stereo Vision

: The active stereo vision is a form of stereo vision which actively employs a light such as **a laser or a structured light** to simplify the stereo matching problem.

- **Conventional structured-light vision (SLV)**
  : employs a structured light or laser, and **finds projector-camera correspondences**

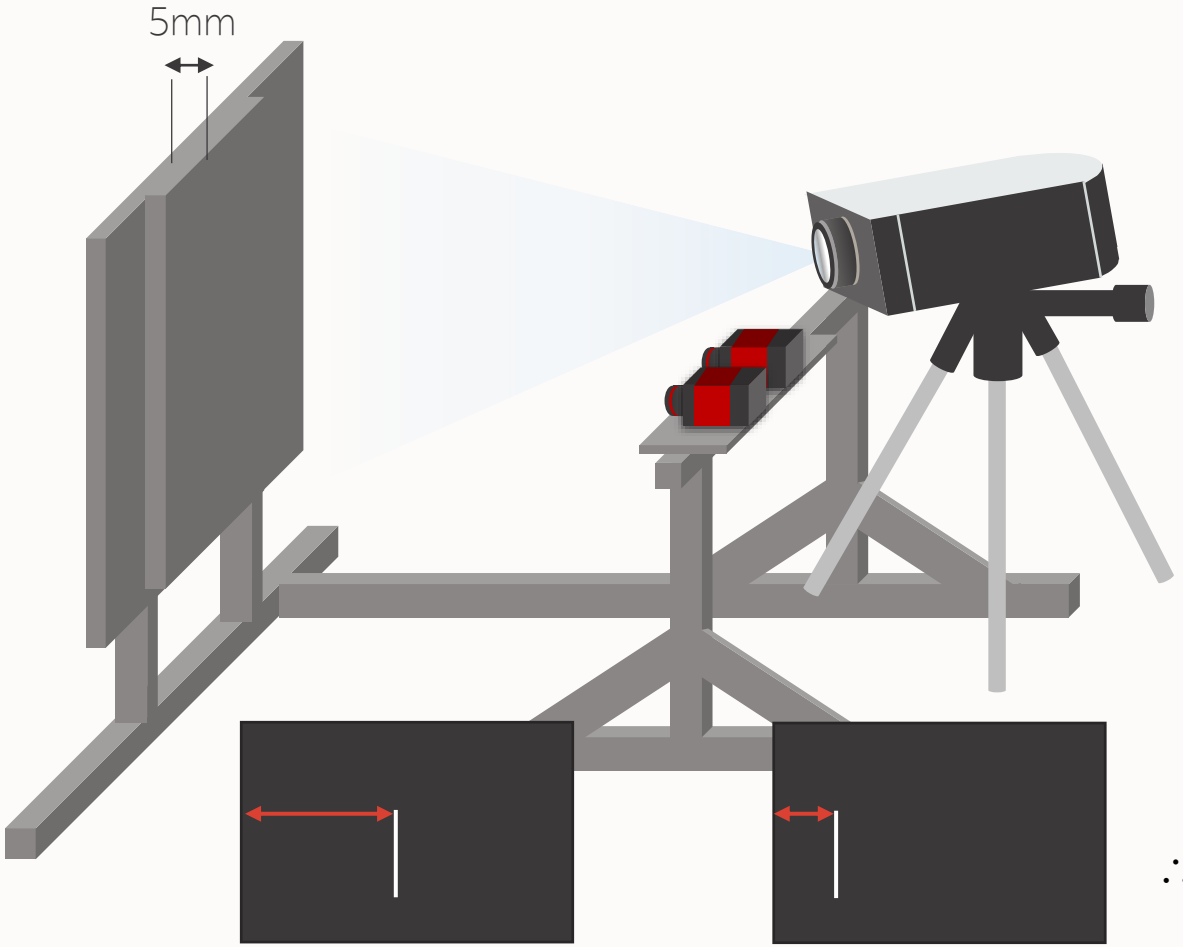
- **Conventional active stereo vision (ASV)**
  : employs a structured light or laser, however, the stereo matching is performed only for camera-camera correspondences, in **the same way as the passive stereo vision.**

- **Structured-light stereo(SLS)**
  : a hybrid technique, which **utilizes both camera-camera and projector-camera correspondences.**

Introduction

Active Stereo Vision

❖ Active Stereo Vision



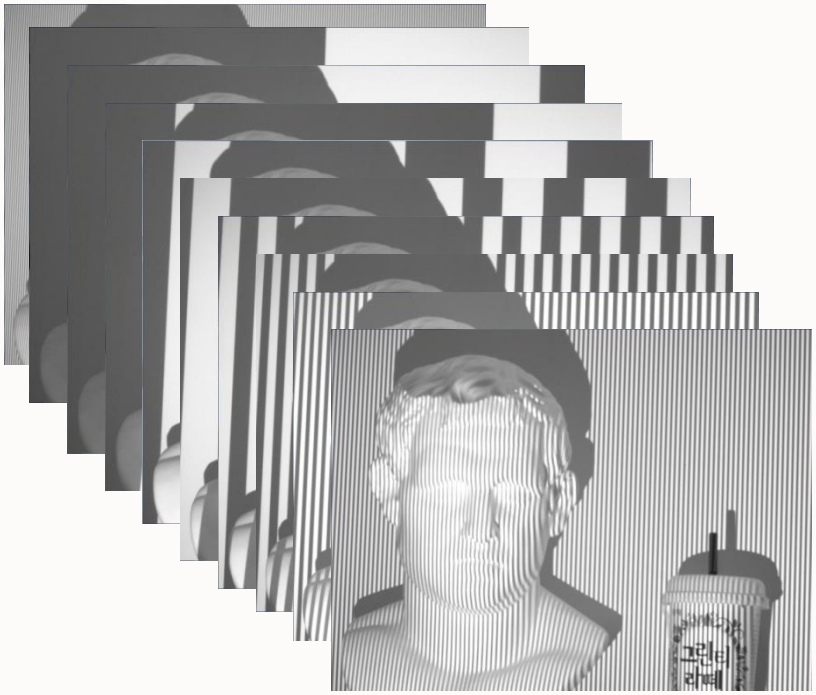
$$\therefore Z = \frac{bf}{x_l - x_r}$$

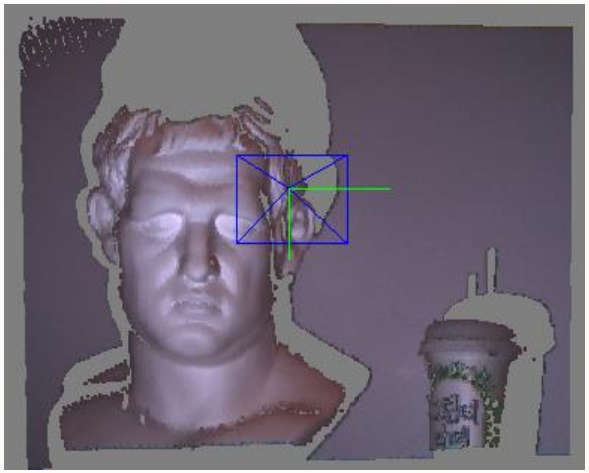
Active Stereo Vision

Structured light

❖ Structured light

: Structured light is the process of projecting **a known pattern (often grids or horizontal bars)** on to a scene. The way that these deform when striking surfaces allows vision systems **to calculate the depth and surface information of the objects** in the scene.





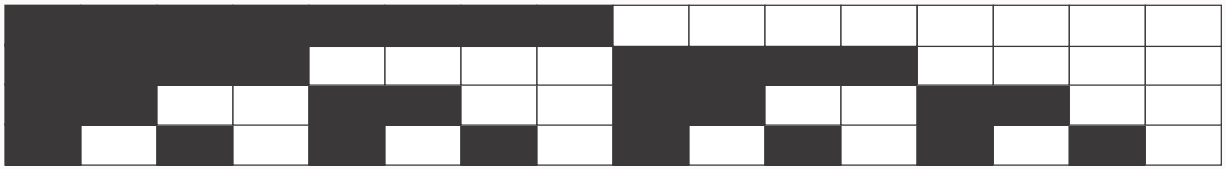
Active Stereo Vision

Structured light

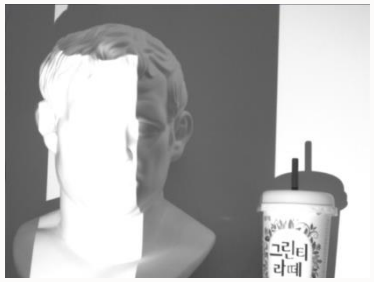
❖ Binary Code

$2^n = X$ n : the number of image
X : resolution

eg. 1024x768 : 10 images



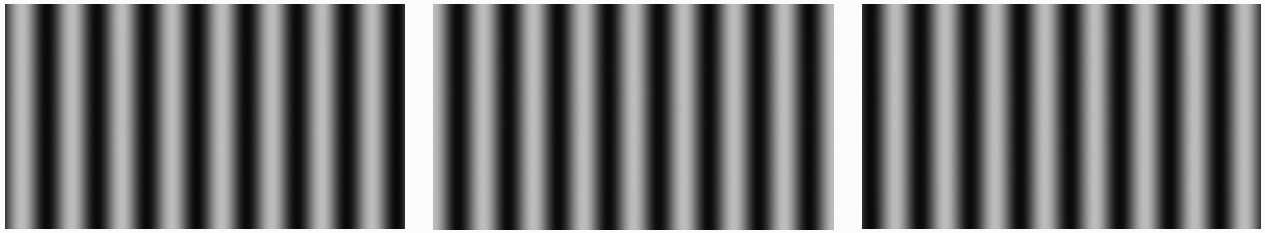
0	0	0	0	0	0	0	0	8	8	8	8	8	8	8	8
0	0	0	0	4	4	4	4	0	0	0	0	4	4	4	4
0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2
0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15



Active Stereo Vision

Structured light

- **Phase shifting method**
  : using a relatively small number of images.



0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Active Stereo Vision

Structured light

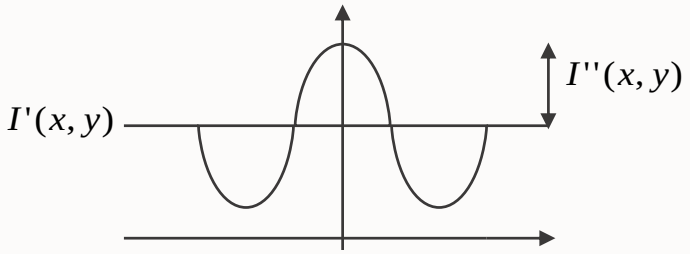
Four step algorithm

$$I_1(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y)]$$

$$I_2(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y) + \frac{\pi}{2}]$$

$$I_3(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y) + \pi]$$

$$I_4(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y) + \frac{3}{2}\pi]$$



Using simple trigonometric identity

$$I_1(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y)]$$

$$I_2(x,y) = I'(x,y) - I''(x,y)\sin[\phi(x,y)]$$

$$I_3(x,y) = I'(x,y) - I''(x,y)\cos[\phi(x,y)]$$

$$I_4(x,y) = I'(x,y) + I''(x,y)\sin[\phi(x,y)]$$

$$I_4 - I_2 = 2I''(x,y)\sin[\phi(x,y)]$$

$$I_1 - I_3 = 2I''(x,y)\cos[\phi(x,y)]$$

$$\frac{I_4 - I_2}{I_1 - I_3} = \frac{\sin[\phi(x,y)]}{\cos[\phi(x,y)]} = \tan[\phi(x,y)]$$

$$\phi(x,y) = \tan^{-1}\left[\frac{I_4 - I_2}{I_1 - I_3}\right]$$

Active Stereo Vision

Structured light

❖ Three step algorithm

$$I_1(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y) - \alpha]$$

$$I_2(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y)]$$

$$I_3(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y) + \alpha]$$

Using the trigonometric addition identities

$$I_1(x,y) = I'(x,y) + I''(x,y)\{\cos[\phi(x,y)]\cos(\alpha) + \sin[\phi(x,y)\sin(\alpha)]\}$$

$$I_2(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y)]$$

$$I_3(x,y) = I'(x,y) + I''(x,y)\{\cos[\phi(x,y)]\cos(\alpha) - \sin[\phi(x,y)\sin(\alpha)]\}$$

Active Stereo Vision

Structured light

❖ Three step algorithm

cf. Four step algorithm

$$I_4 - I_2 = 2I''(x,y)\sin[\phi(x,y)]$$

$$I_1 - I_3 = 2I''(x,y)\cos[\phi(x,y)]$$

$$\frac{I_4 - I_2}{I_1 - I_3} = \frac{\sin[\phi(x,y)]}{\cos[\phi(x,y)]} = \tan[\phi(x,y)]$$

$$I_1 - I_3 = 2I''(x,y)\sin[\phi(x,y)]\sin(\alpha)$$

$$I_2 - I_1 = I''(x,y)\cos[\phi(x,y)]\{1-\cos(\alpha)\} - I''(x,y)\sin[\phi(x,y)]\sin(\alpha)$$

$$I_2 - I_3 = I''(x,y)\cos[\phi(x,y)]\{1-\cos(\alpha)\} + I''(x,y)\sin[\phi(x,y)]\sin(\alpha)$$

$$2I_2 - I_1 - I_3 = 2I''(x,y)\cos[\phi(x,y)]\{1-\cos(\alpha)\}$$

Active Stereo Vision

Structured light

❖ Three step algorithm

$$I_1 - I_3 = 2I''(x,y)\sin[\phi(x,y)]\sin(\alpha)$$

$$2I_2 - I_1 - I_3 = 2I''(x,y)\cos[\phi(x,y)]\{1-\cos(\alpha)\}$$

$$\frac{I_1 - I_3}{2I_2 - I_1 - I_3} = \frac{2I''(x,y)\sin[\phi(x,y)]\sin(\alpha)}{2I''(x,y)\cos[\phi(x,y)]\{1-\cos(\alpha)\}}$$

$$= \frac{\sin[\phi(x,y)]\sin(\alpha)}{\cos[\phi(x,y)]\{1-\cos(\alpha)\}} = \frac{\sin(\alpha)}{1-\cos(\alpha)}\tan(\phi(x,y))$$

$$\phi(x,y) = \tan^{-1}\left\{\left[\frac{1-\cos(\alpha)}{\sin(\alpha)}\right]\frac{I_1 - I_3}{2I_2 - I_1 - I_3}\right\}$$

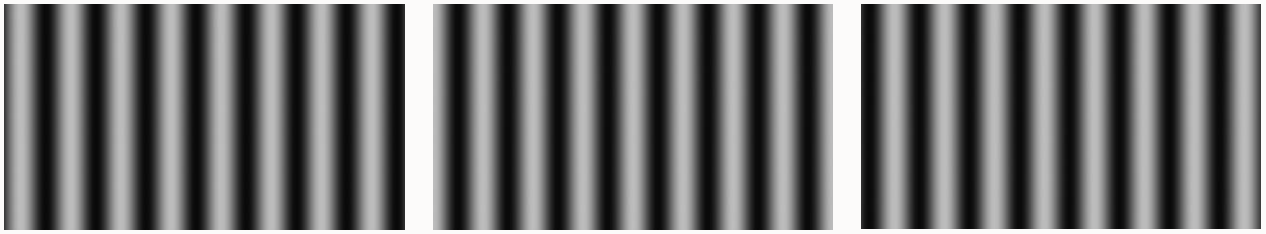
$$when\ \alpha = \frac{3\pi}{2}$$

$$\phi(x,y) = \tan^{-1}\left(\sqrt{3}\,\frac{I_1 - I_3}{2I_2 - I_1 - I_3}\right)$$

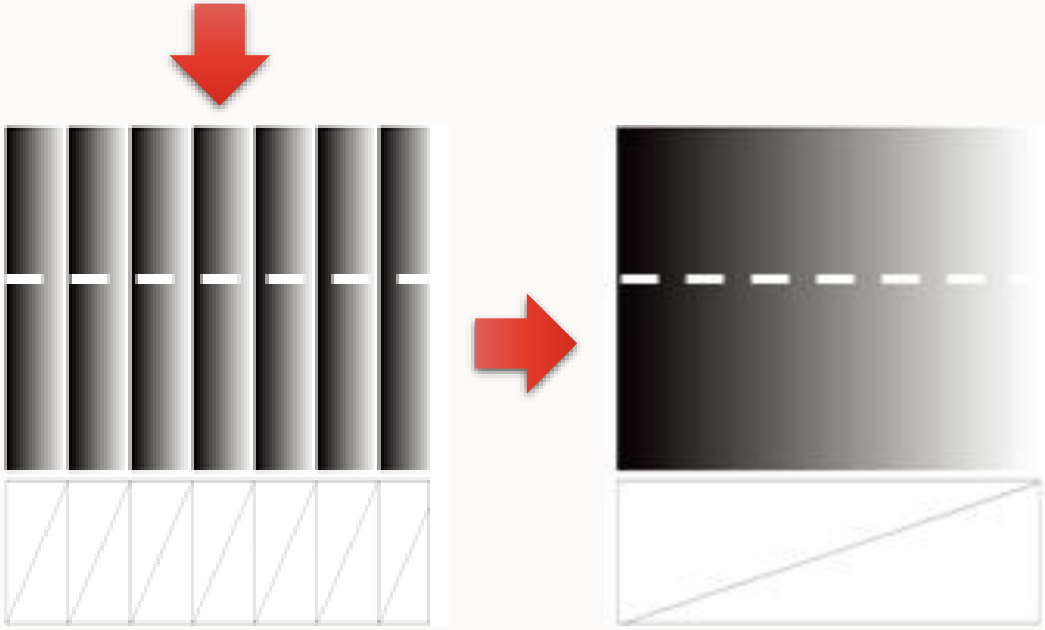
Active Stereo Vision

Structured light

❖ Unwrapping



Phase Image



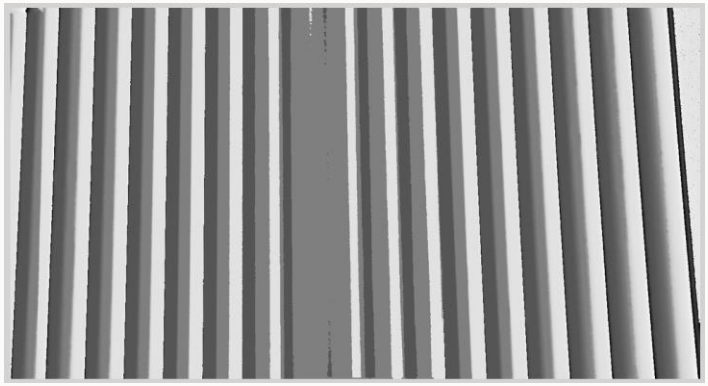
Before unwrapping (0~2π)

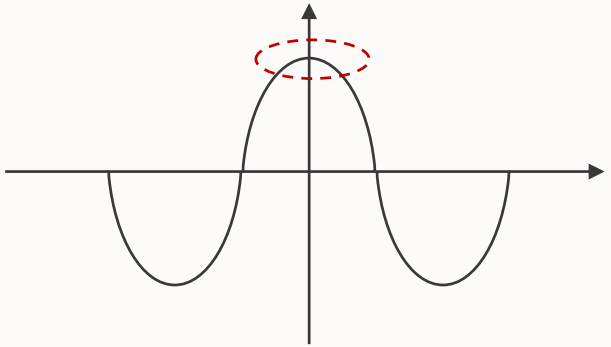
After unwrapping

Active Stereo Vision

Experimental results

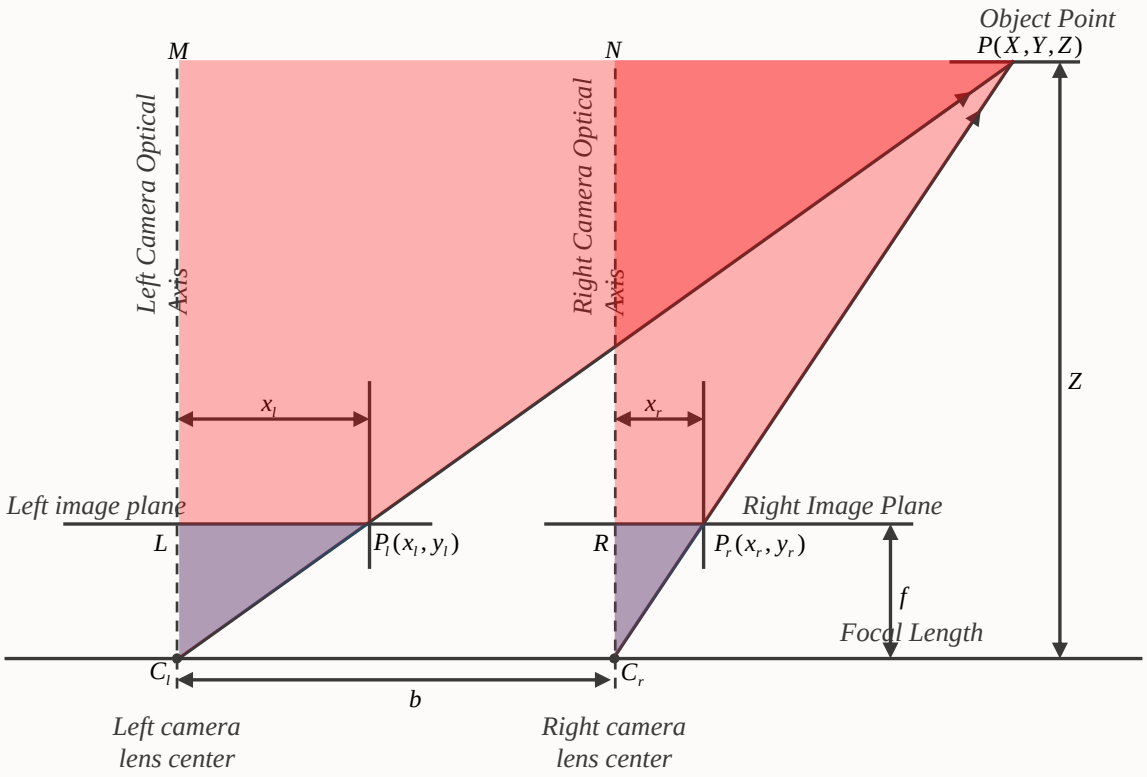
❖ Experimental results (Three step algorithm)





Q & A

Thank You!!!



$\Delta PMC_l \overset{similar}{\longleftrightarrow} \Delta P_l LC_l$

$$\frac{X}{Z} = \frac{x_l}{f} \quad \text{——— a}$$

$\Delta PNC_r \overset{similar}{\longleftrightarrow} \Delta P_r RC_r$

$$\frac{X-b}{Z} = \frac{x_r}{f} \quad \text{——— b}$$

from a $X = \frac{x_l}{f} Z$ from b $X = \frac{x_r}{f} Z + b$

$$\frac{x_l}{f} Z = \frac{x_r}{f} Z + b, \quad \frac{x_l - x_r}{f} Z = b$$

$$\therefore Z = \frac{bf}{x_l - x_r}$$ ⇒ We need to disparity information